Evolution Of Particle Size In Turbid Discharge Plumes

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LONG-TERM GOALS

The goals of this research are to develop greater understanding of the fate of the sediment delivered to the continental shelf by the Eel River during floods and to refine methods for interpreting quantitatively the environmental record stored in grain size distributions of fine sediments on the shelf.

SCIENTIFIC OBJECTIVES

The proposed research has three objectives.

- Develop and test energy-based parameterization of floc settling velocity.
- Monitor patterns of post-event, cross-shelf transport of flood sediment in the bottom boundary layer (BBL).
- Refine and test models for quantitative process-based interpretation of disaggregated inorganic grain size (DIGS) in suspension and in the seabed.

APPROACH

The field effort employs a rapid response strategy, in which preset stream flow levels in the Eel River elicit a mobilization of people and gear. Within 24 hours of a “trigger," an instrument package comprising a CTD, optical backscatter sensor, silhouette floc camera (SFC), and 2 depth-actuated Niskin bottles is ready to be deployed from a Coast Guard helicopter. In 1999 two additional samplers were added to the instrument package: a bottom-actuated syringe for collecting samples of suspension within the bottom boundary layer and a bottom-actuated micro-grab sampler for collecting samples of surficial sediment. The instrument package is lowered on a wire into the water on a grid of 9-12 stations in the Eel River plume. Stations extend from just seaward of the surf zone to 40 meters water depth. Stations are occupied during the flood and for several days afterward, allowing examination of the post- flood distribution of suspended sediment on the shelf.

Analysis of DIGS focuses on process-based parameterization of fine-sediment grain size distributions. The parameterization divides a deposit into floc-delivered and single-grain delivered fractions. These distinctions are more valuable from a dynamic standpoint than typical sand-silt-clay ratios because they relate directly to mode of transport. This parameterization is being applied to closely spaced samples of x-radiographed slabs from box cores taken by Rob Wheatcroft on the Eel shelf.

All work is being conducted collaboratively with Paul Hill of Dalhousie University. Milligan takes primary responsibility for equipment design, data acquisition, and particle size analysis. Hill takes primary responsibility for modeling, data analysis, and communication of results.

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WORK COMPLETED

In winter 1999 particle size distributions were monitored during and after one flood event on 4 helicopter missions. SFC photos for each mission have been digitized. Water samples have been analyzed for SPM, and disaggregated grain size distributions have been generated with a Coulter Multisizer. Also, disaggregated size distributions have been generated for a variety of cores on the Eel shelf.

A manuscript exploring the controls on effective settling velocity of sediment in the Eel plume was prepared and submitted in July, 1999 to a Continental Shelf Research special volume on event sedimentation on the continental shelf. This manuscript made use of sediment concentration, salinity, and floc size data gathered by Milligan, Hill and Rocky Geyer in the 1997 and 1998 flood seasons. It also made use of velocity data gathered on moorings.

Contributions were made to a manuscript on the structure of the Eel River plume put together by Geyer and submitted to the same special volume in September 1999. This manuscript explored the controls on plume structure and sediment fate.

RESULTS

Bulk effective settling velocities required to explain sinking losses from the Eel River flood plume off the coast of northern California are of order 0.1 mm s^{-1} for five different helicopter-based sampling surveys conducted in January and February 1998. These effective settling velocities exceed those expected by single-grain sinking by a factor of two and implicate flocculation as an important mechanism for speeding the removal of sediment from the Eel River plume. The relative constancy of effective clearance rates despite widely varying winds, waves, and currents is consistent with photographs in the plume that show little variability in floc size with day, depth, or across- and along-shelf position. These observations of floc size contrast with those made in winter 1997 during the exceptionally large New Year's flood. During that event, increases of floc size with depth are evident. In 1997, higher sediment concentrations associated with the significantly larger discharge allowed flocs to grow substantially as they sank through the plume, whereas in 1998 low concentrations precluded significant increases in floc size with depth. These observations do not support the hypothesis that concentration controls maximal floc size; rather they indicate that the time required to form large flocs scales inversely with concentration. Using a published relationship between floc size and settling velocity for the Eel shelf suggests that approximately one half of the sediment in the plume was packaged as flocs during the 1998 floods. These data provide unique quantification of the role of flocculation in determining clearance rates from riverine discharge plumes, thus advancing efforts to develop a process-based understanding of flood deposits on continental shelves.

Total SPM and disaggregated inorganic grain size analyses of samples collected 0.05m off the bottom by the suction sampler show that the sand fraction is limited to the benthic boundary layer in the river mouth and on the shelf. Samples collected at 1.5 m depth from the river mouth in 1999 and previous years did not have significant amounts of material > 63 microns in them. Restricting the sand fraction to the near bottom region of the river will affect sediment budget estimates based on the rating curve for the Eel River. Concentrations were found to be highest near the bottom throughout the sampling period for 1999 which supports the hypothesis that fine-grained sediment deposited from the plume is concentrated at the seabed in the near shelf region.

Analysis of disaggregated grain size distributions in sediment cores collected in the region of the fine grained mud deposit shows that well-sorted fine sands underlie poorly sorted flood-deposited muds. This observation suggests that flood deposits may be ephemeral and eventually will be destroyed by physical processes.

IMPACT/APPLICATION

Observations are helping to refine understanding of modes of delivery of flood sediment to the Eel River Shelf. These observations will allow quantitative constraint of aggregation time scales that has been lacking in the past.

TRANSITIONS

No transitions have occurred to date.

RELATED PROJECTS

Controls on floc size in tidal rivers in South Carolina is being investigated in collaboration with Gail Kineke (Boston College) and Clark Alexander (Skidaway Institute of Oceanography).

Controls on floc size on the Grand Banks of Newfoundland are being investigated with a team of researchers from the Bedford Institute of Oceanography.

Floc size is being assessed in a time series study of bloom properties in Bedford Basin. Collaborators are Erin Hildebrand (Dalhousie University) and researchers from the Bedford Institute of Oceanography.

PUBLICATIONS

Curran, K. J., P. S. Hill, and T. G. Milligan. The role of particle aggregation in size dependent deposition of drill wastes. Geo-Marine Letters, submitted August, 1999.

Geyer, W. R., P. S. Hill, T. G. Milligan, and P. Traykovski. The structure of the Eel River plume during floods. Continental Shelf Research, submitted September, 1999.

Hill, P. S., T. G. Milligan, and W. R. Geyer. Controls on effective settling velocity in the Eel River flood plume, Continental Shelf Research, submitted July, 1999.